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DESCRIPTION

ETCHING SOLUTION, ETCHED ARTICLEAND METHOD FOR ETCHED ARTICLETECHNICAL FIELD

5 The present invention relates to an etching
solution, a method for producing an etched article and an
etched article produced by the method, more specifically,
an etching solution and a method for producing an etched
article for selectively etching a doped oxide film,
10 particularly BSG or BPSG relative to an undoped oxide
film, particularly THOX, and an etched article produced
by the method.

BACKGROUND ART

Conventionally, as etchants for silicon wafers
15 and the like have been used buffered hydrofluoric acids
comprising HF (50% by weight) and NH_4F (40% by weight) at
such a ratio that can achieve a desired etch rate.

However, the buffered hydrofluoric acids etch
not only doped oxide films such as BSG films, BPSG films,
20 phosphosilicate glass (PSG) films, arsenic silicate glass
(AsSG) films and the like, but also undoped oxide films
such as USG including TEOS (oxide obtained by CVD method
using tetraethoxysilane gas) films, THOX and the like.
Therefore, the buffered hydrofluoric acids can not
25 selectively etch the doped oxide films.

An object of the present invention is to provide an etching solution and an etching method for selectively etching oxide films doped with impurities relative to TEOS and THOX.

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DISCLOSURE OF INVENTION

The present invention relates to the items 1-16 listed below.

Item 1: An etching solution comprising hydrofluoric acid, wherein an a ratio of etch rate of a boron silicate glass film (BSG) or boron phosphosilicate glass / an etch rate of a thermal oxide film (THOX) at 25°C is 10 or higher.

Item 2: The etching solution according to item 1, wherein a solvent in the etching solution has a relative dielectric constant of 61 or lower.

Item 3: The etching solution according to item 1, the solution containing at least one member selected from the group consisting of an organic acid and an organic solvent having a hetero atom.

Item 4: The etching solution according to item 1, the solution containing (i) water and (ii) at least one member selected from the group consisting of an organic acid and an organic solvent having a hetero atom, the water being contained in a concentration of 70% by weight or lower.

Item 5: The etching solution according to item 1,

wherein the weight ratio of HF : isopropyl alcohol :
water is 0.1-50% by weight : 30-99% by weight : 0-70% by
weight.

Item 6: The etching solution according to item 1,

- 5 wherein the weight ratio of HF : acetic acid : water is
0.1-50% by weight : 30-99.9% by weight : 0-70% by weight.

Item 7: The etching solution according to item 1,
wherein the weight ratio of HF : tetrahydrofuran : water
is 0.1-50% by weight : 30-99.9% by weight : 0-70% by
10 weight.

Item 8: The etching solution according to item 1,
wherein the weight ratio of HF : acetone : water is 0.1-
50% by weight : 30-99.9% by weight : 0-70% by weight.

- Item 9: The etching solution according to item 1,
15 wherein the weight ratio of HF : methanol : water is 0.1-
50% by weight : 30-99.9% by weight : 0-70% by weight.

Item 10: The etching solution according to item 1,
wherein the weight ratio of HF : ethanol : water is 0.1-
50% by weight : 30-99.9% by weight : 0-70% by weight.

- 20 Item 11: The etching solution according to item 1, the
solution comprising an inorganic acid.

Item: 12 The etching solution according to item 11,
wherein the inorganic acid has a pKa value at 25°C of 2
or lower.

- 25 Item 13: The etching solution according to item 11,

wherein the weight ratio of HF : HCl : water is 0.01-50%
by weight : 1-36% by weight : 0-99% by weight.

Item 14: The etching solution according to item 11,
wherein the weight ratio of HF : HNO₃ : water is 0.01-50%

5 by weight : 1-70% by weight : 0-99% by weight.

Item 15: A method for producing an etched article by
etching an article to be etched with the etching solution
as defined in any of items 1-14.

Item 16: An etched article which is obtainable by the
10 method of item 15.

According to the etching solution of the
invention, the ratio of BSG etch rate / THOX etch rate
and/or the ratio of BPSG etch rate / THOX etch rate at
25°C is/are 10 or higher, preferably 20 or higher, more
15 preferably 50 or higher, particularly 100 or higher.

In case of using TEOS instead of THOX, the
ratio of BSG etch rate / TEOS etch rate and/or the ratio
of BPSG etch rate / TEOS etch rate at 25°C is/are 5 or
higher, preferably 10 or higher, more preferably 50 or
20 higher, particularly 100 or higher.

The etch rate of the etching solution of the
invention can be calculated as the difference in
thickness of a film (BSG; BPSG; THOX; TEOS and like USG,
etc.) before and after etching divided by etch time.

25 The water content is not higher than 70% by

weight, preferably not higher than 30% by weight, more preferably about 30-5% by weight. The relative dielectric constant of the etching solution expresses an arithmetic mean of the relative dielectric constants of the

- 5 components of the etching solutions other than the HF and inorganic acid.

Preferable examples of the inorganic acid include inorganic acids having a pKa value at 25°C of 2 or lower, for example, hydrochloric acid (pKa = -8),
10 nitric acid (pKa = -1.8), hydrobromic acid (pKa = -9), hydroiodic acid (pKa = -10) and perchloric acid (a pKa-unmeasurably strong acid).

Examples of the organic acid include acetic acid (relative dielectric constant: 6.15 (20°C)),
15 propionic acid (relative dielectric constant: 3.4 (40°C)), butyric acid (relative dielectric constant: 2.97 (20°C)), isobutyric acid (relative dielectric constant: 2.73 (40°C)), valeric acid, caproic acid (relative dielectric constant: 2.63 (71°C)), caprylic acid (relative
20 dielectric constant: 2.45 (20°C)), monochloroacetic acid (relative dielectric constant: 21 (20°C)), dichloroacetic acid (relative dielectric constant: 8.08 (20°C)), trichloroacetic acid (relative dielectric constant: 4.6 (60°C)), monofluoroacetic acid, difluoroacetic acid,
25 trifluoroacetic acid, α -chlorobutyric acid, β -

chlorobutyric acid, γ -chlorobutyric acid, lactic acid
(relative dielectric constant: 22(70°C)), glycolic acid,
pyruvic acid, glyoxalic acid, acrylic acid and like
monocarboxylic acids, methanesulfonic acid,

- 5 toluenesulfonic acid and like sulfonic acids, oxalic acid,
succinic acid, adipic acid, tartaric acid, citric acid
and like polycarboxylic acids.

- Examples of the organic solvent having a hetero
atom include methanol (relative dielectric constant: 32.6
10 (25°C)), ethanol (relative dielectric constant: 24.6
(25°C)), isopropanol (IPA, relative dielectric constant:
19.9 (25°C)), 1-propanol (relative dielectric constant:
22.2 (25°C)), 1-butanol (relative dielectric constant:
17.1 (25°C)), 2-butanol (relative dielectric constant:
15 15.5 (19°C)), t-butanol (relative dielectric constant:
11.4 (19°C)), 2-methyl-1-propanol (relative dielectric
constant: 17.95 (20°C)), 1-pentanol (relative dielectric
constant: 13.9 (25°C)), 1-hexanol (relative dielectric
constant: 13.3 (25°C)), 1-heptanol, 4-heptanol, 1-octanol
20 (relative dielectric constant: 10.34 (20°C)), 1-
nonylalcohol, 1-decanol, 1-dodecanol and like alcohols;
ethylene glycol (relative dielectric constant: 37.7
(20°C)), 1,2-propanediol (relative dielectric constant:
32.0 (20°C)), 2,3-butanediol, glycerin (relative
25 dielectric constant: 42.5 (25°C)) and like polyols,

acetone (relative dielectric constant: 20.7 (25°C)),
acetylacetone, methyl ethyl ketone (relative dielectric
constant: 18.51 (20°C)) and like ketones; acetonitrile
(relative dielectric constant: 37.5 (20°C)),

5 propionitrile (relative dielectric constant: 29.7 (20°C)),
butyronitrile (relative dielectric constant: 20.3 (20°C)),
isobutyronitrile (relative dielectric constant: 20.4
(20°C)), benzonitrile (relative dielectric constant: 25.2
(25°C)) and like nitriles; formaldehyde, acetaldehyde,
10 propionaldehyde and like aldehydes; ethylene glycol
monomethyl ether, ethylene glycol monoethyl ether and
like alkylene glycol mono alkyl ethers; tetrahydrofuran
(relative dielectric constant: 7.6 (25°C)), dioxane
(relative dielectric constant: 2.2 (25°C)) and like
15 ethers, trifluoroethanol, pentafluoropropanol, 2,2,3,3-
tetrafluoro propanol and like fluorine alcohols,
sulfolane (relative dielectric constant: 43.3 (20°C)),
nitromethane (relative dielectric constant: 35.87 (30°C))
and the like.

20 The relative dielectric constant of water is
78.3 (25°C).

The content of HF is about 0.01-50% by weight,
preferably about 1-5% by weight.

The water content is not higher than 70% by
25 weight, preferably not higher than 30% by weight, more

preferably about 0-5% by weight.

The content of the inorganic acid is about 1-99% by weight, preferably about 30-70% by weight.

The content of the organic acid is about 30-99.9% by weight, preferably about 70-99.9% by weight.

The content of the organic solvent having a hetero atom is about 30-99.9% by weight, preferably about 70-99.9% by weight.

The content of at least one member selected from the group consisting of the inorganic acid, organic acid and organic solvent having a hetero atom is about 30-99.9% by weight, preferably about 70-99.9% by weight.

The inorganic acid has a pKa at 25°C of about 2 or lower, preferably about -5 or lower.

The relative dielectric constant of the organic acid and organic solvent having an hetero atom is preferably about 40 or lower, more preferably about 10 or lower.

As the HF is usually used dilute hydrofluoric acid (50 wt. % aqueous solution). However, when the HF does not contain water, 100% HF may be also used.

In case of HCl, HBr and HI, an anhydrous etching solution can be prepared by blowing these gases through the etching solution.

Preferable etching solutions of the present

invention and their compositions are shown below.

·HF: IPA : water = 1-10% by weight : 70-99% by weight :
0-30% by weight

·HF: acetic acid : water = 0.5-5% by weight : 70-99.5% by
5 weight : 0-30% by weight

·HF : HCl : water = 0.01-5% by weight : 1-36% by weight :
50-99% by weight

·HF : nitric acid : water = 0.01-5% by weight : 1-70% by
weight : 20-99% by weight

10 ·HF: acetone : water = 1-10% by weight : 70-99% by
weight : 0-30% by weight

·HF: THF : water = 1-10% by weight : 70-99% by weight :
0-30% by weight

·HF: methanol : water = 1-10% by weight : 70-99% by
15 weight : 0-30% by weight

·HF: ethanol : water = 1-10% by weight : 70-99% by
weight : 0-30% by weight

The etching solution of the invention can be
suitably used for selectively etching a doped oxide film
20 of an article to be etched comprising an oxide film (BSG,
BPSG, etc.) doped with B, P and the like and an undoped
oxide film such as THOX, TEOS and like.

In the etching method of the present invention,
the temperature of the etching solution is about 15-40°C.

25 Examples of the article to be etched include

single crystalline silicon wafers, gallium-arsenic wafers and like wafers, especially the articles comprising a doped oxide film (BSG, BPSG, etc.) and an undoped oxide film (THOX, TEOS and like USGs).

5 The BSG etch rate of the etching solution of the invention is usually about 10-2000 nm/min, preferably about 40-500 nm/min.

10 The present invention can provide an etching solution which can selectively etch films doped with impurities, such as BSG, BPSG and the like, relative to THOX, TEOS and like USG, a method for producing an etched article using the etching solution and an etched article.

BEST MODE FOR CARRYING OUT THE INVENTION

15 The present invention will be explained in more detail with referring to Examples and Comparative Examples below.

Examples 1-2 and Comparative Examples 1-4 (inorganic acid)

20 Etching solutions were prepared by mixing HF, water, an organic solvent having a hetero atom (isopropyl alcohol (IPA), THF, acetone, methanol, ethanol), an organic acid (acetic acid) and inorganic acid (HCl, HNO₃) in the ratios shown in Table 1. Test substrates were produced by forming each of a thermal oxide (THOX) film,
25 USG (TEOS) film, boron silicate glass (BSG) film and

boron phosphosilicate glass (BPSG) film on a silicon substrate by CVD method using a tetraethoxysilane gas. The etch rate and etch selectivity of the etching solutions on the test substrates were determined.

5 In addition, the etch rate and selectivity of
conventional HF-H₂O and HF-NH₄F-H₂O etching solutions
were determined in the above-mentioned manner as
Comparative Examples.

The etch rate was determined by measuring the
10 thickness of the films before and after etching with an
Auto EL-III ellipsometer manufactured by Rudolf Research.

The etch rates of the etching solutions were calculated as the difference in thickness of films before and after being etched at 25°C divided by etch time.

15 The results of the etching solutions with each
composition are shown in Table 1 to Table 8.

The relative dielectric constant is that of a solvent (an organic solvent having a hetero atom or an organic acid) + water at 25°C, expressed as a calculated value of an average of the relative dielectric constants of the solvent and water having the particular composition.

Average of relative dielectric constants =
[78.3 x (percentage by weight of water) + (relative
dielectric constant of solvent at 25°C) x (percentage by

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weight of solvent)] / [(percentage by weight of water) +
(percentage by weight of solvent)]

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HF-H₂O-isopropyl alcohol (IPA) etchant

	Sol- vent	Relative dielectric constant of solvent	HF con- cen- tra- tion (%)	Water con- cen- tra- tion (%)	Solvent (IPA) con- cen- tra- tion (%)	Relative dielectric constant of solvent (IPA)+water (calculated value)	THOX etch rate (A/m in.)	TEOS etch rate (A/m in.)	BSG etch rate (A/min)	BSG etch rate (A/m in.)	BSG/ THOX sele ctiv ity	BSG/ THO X sele ctiv ity	BSG/ TEOS sele ctiv ity	BPSG /TEO S sele ctiv ity
Ex. 1	IPA	19.9	5	5	90	23.0	12	11	370	330	31	28	34	30
Ex. 2	IPA	19.9	5	25	70	35.3	55	76	920	1160	17	21	12	15
Ex. 3	IPA	19.9	5	45	50	47.6	97	140	1190	1650	12	17	8.5	12
Ex. 4	IPA	19.9	5	65	30	59.9	140	200	1450	1950	10	14	7.3	9.8
Ex. 5	IPA	19.9	3	3	94	21.7	2	3	120	-	60	-	40	-
Ex. 6	IPA	19.9	10	10	80	26.4	59	82	2200	-	37	-	27	-
Ex. 7	IPA	19.9	15	15	70	30.2	350	230	6500	-	28	-	19	-
Ex. 8	IPA	19.9	20	20	60	34.5	820	1200	12000	-	15	-	10	-
Comp. Ex. 1	(Water)	(78.3)	1	99	0	-	58	93	380	-	6.5	-	4.1	-
Comp. Ex. 2	(Water)	(78.3)	2	98	0	-	120	190	750	-	6.3	-	3.9	-
Comp. Ex. 3	(Water)	(78.3)	3	95	0	-	300	490	1980	-	6.6	-	4.0	-

HF-H₂O-acetic acid etchant

Ex.	Solvent	Relative dielectric constant of solvent	HF concentration (%)	Water concentration (%)	Solvent (acetic acid) concentration (%)	Relative dielectric constant of solvent (acetic acid)+ water (calculated value)	THOX etch rate (A/mi n.)	TEOS etch rate (A/mi n.)	BSG etch rate (A/mi n.)	BPSG etch rate (A/mi n.)	BSG/T HOX selectivity	BPSG/THOX selectivity	BSG/T EOS selectivity	BPSG/TEOS selectivity
Ex. 9	Acetic acid	6.15	1	1	98	6.88	10	14	530	750	53	75	38	54
Ex. 10	Acetic acid	6.15	1.25	1.25	97.5	7.06	12	18	1200	940	100	78	67	52
Ex. 11	Acetic acid	6.15	1.5	1.5	97	7.25	17	22	1600	1300	94	76	73	59
Ex. 12	Acetic acid	6.15	2	2	96	7.62	25	33	2600	-	100	-	79	-
Ex. 13	Acetic acid	6.15	2.5	2.5	95	8	32	45	3600	-	110	-	80	-
Ex. 14	Acetic acid	6.15	3	3	94	8.38	40	55	4600	-	120	-	84	-
Ex. 15	Acetic acid	6.15	5	5	90	9.95	97	140	8900	-	92	-	64	-
Ex. 16	Acetic acid	6.15	1.25	5	93.75	9.80	18	23	1600	-	89	-	70	-
Ex. 17	Acetic acid	6.15	1.25	10	88.75	13.5	20	32	1300	-	65	-	41	-
Ex. 18	Acetic acid	6.15	1.25	20	78.75	20.8	32	46	970	-	30	-	21	-
Ex. 19	Acetic acid	6.15	1.25	30	68.75	28.1	39	58	830	-	21	-	14	-
Ex. 20	Acetic acid	6.15	1.25	40	58.75	35.4	40	65	670	-	17	-	10	-
Ex. 21	Acetic acid	6.15	1.25	50	48.75	42.7	43	72	590	-	14	-	8.2	-

TABLE 3

HF-H₂O-tetrahydrofurane (THF) etchant

	Sol-vent	Relative dielectric constant of solvent	HF con-centration (%)	Water con-centration (%)	Sol-vent (THF) con-centration (%)	Relative dielectric constant of solvent (THF)+water (calculated value)	THOX etch rate (A/m in.)	TEOS etch rate (A/m in.)	BSG etch rate (A/m in.)	BPSG etch rate (A/m in.)	BSG/THOX sele ctiv ity	BPSG/THO X sele ctiv ity	BSG/TEOS sele ctiv ity	BPSG/TEO S sele ctiv ity
Ex. 22	THF	7.6	5	5	90	11.3	3	4	510	330	170	110	130	83
Ex. 23	THF	7.6	5	25	70	26.2	31	42	690	830	22	27	16	20
Ex. 24	THF	7.6	5	45	50	41.1	64	85	890	1200	14	19	10	14
Ex. 25	THF	7.6	5	65	30	56.0	110	150	1200	1600	11	15	8	11

HF-H₂O-acetone etchant

	Solvent	Relative dielectric constant of solvent	HF concentration (%)	Water concentration (%)	Solvent (acetone) concentration (%)	Relative dielectric constant of solvent (acetone)+ water (calculated value)	THOX etch rate (A/m in.)	TEOS etch rate (A/m in.)	BSG etch rate (A/m in.)	BSG/THOX selectivity	BPSG/THOX selectivity	BSG/TEOS selectivity	BPSG/TEOS selectivity
Ex. 26	Acetone	20.7	5	5	90	23.7	3	4	410	250	140	83	63
Ex. 27	Acetone	20.7	5	25	70	35.9	24	29	440	520	18	22	18
Ex. 28	Acetone	20.7	5	45	50	48.0	49	67	620	760	13	16	11
Ex. 29	Acetone	20.7	5	65	30	60.1	96	140	960	1300	10	14	9.3

HF-H₂O-methanol etchant

	Solvent	Relative dielectric constant of solvent	HF concentration (%)	Water concentration (%)	Solvent (methanol) concentration (%)	Relative dielectric constant of solvent (methanol)+water (calculated value)	THOX etch rate (A/m in.)	TEOS etch rate (A/m in.)	BSG etch rate (A/m in.)	BPSG etch rate (A/m in.)	BSG/THOX selectivity	BPSG/THOX selectivity	BSG/TEOS selectivity	BPSG/TEOS selectivity
Ex. 30	Methanol	32.6	3	3	94	34.0	0.5	7	44	73	88	150	6.3	10
Ex. 31	Methanol	32.6	5	5	90	35.0	3	9	170	230	57	77	19	26
Ex. 32	Methanol	32.6	10	10	80	39.9	22	43	730	410	33	19	17	9.5

HF-H₂O-ethanol etchant

	Solvent	Relative dielectric constant of solvent	HF concentration (%)	Water concentration (%)	Solvent (ethanol) concentration (%)	Relative dielectric constant of solvent (ethanol) + water (calculated value)	THOX etch rate (A/m in.)	TEOS etch rate (A/m in.)	BSG etch rate (A/m in.)	BPSG etch rate (A/m in.)	BSG/THOX selectivity	BPSG/THOX selectivity	BSG/TEOS selectivity	BPSG/TEOS selectivity
Ex. 33	Ethanol	24.6	5	5	90	27.4	7	9	250	210	36	30	28	23

HF-NH₄F-H₂O etchant (Comparative Examples)

	Solvent	Relative dielectric constant of solvent	HF concentration (%)	NH ₄ F concentration (%)	Solvent (water) concentration (%)	THOX etch rate (A/m in.)	TEOS etch rate (A/m in.)	BSG etch rate (A/m in.)	BPSG etch rate (A/m in.)	BSG/THOX selectivity	BPSG/THOX selectivity	BSG/TEOS selectivity	BPSG/TEOS selectivity
Comp. Ex. 4	(Water)	(78.3)	1	39.1	59.9	170	230	110	-	0.6	-	0.5	-
Comp. Ex. 5	(Water)	(78.3)	2	2	96	280	480	620	-	2.2	-	1.3	-
Comp. Ex. 6	(Water)	(78.3)	2	5	93	320	640	440	-	1.4	-	0.7	-
Comp. Ex. 7	(Water)	(78.3)	2	10	88	400	700	350	-	0.9	-	0.5	-
Comp. Ex. 8	(Water)	(78.3)	2	20	78	420	720	270	-	0.6	-	0.4	-
Comp. Ex. 9	(Water)	(78.3)	2	30	68	390	610	230	-	0.6	-	0.4	-
Comp. Ex. 10	(Water)	(78.3)	2	38.7	59.3	300	450	200	-	0.7	-	0.4	-

[illegible]

	Added acid	pKa of acid	HF concentration (%)	Water concentration (%)	Acid concentration (%)	THOX etch rate (A/m in.)	TEOS etch rate (A/m in.)	BSG etch rate (A/m in.)	BPSG/THOX selectivity	BPSG/THOX selectivity	BSG/TEOS selectivity	BPSG/TEOS selectivity
Ex. 34	HCl	-8	0.1	64	35.9	17	32	440	-	26	14	-
Ex. 35	HCl	-8	0.25	63.9	35.8	53	89	1200	-	23	13	-
Ex. 36	HCl	-8	0.5	63.9	35.6	120	200	2500	-	21	13	-
Ex. 37	HCl	-8	0.75	63.8	35.5	180	300	4300	-	24	14	-
Ex. 38	HCl	-8	1	63.7	35.3	240	380	4500	-	19	12	-
Ex. 39	HNO ₃	-1.8	1	30.4	68.6	240	340	5300	-	22	16	-
Comp. Ex.	H ₃ PO ₄	2.15	1	15.7	83.3	120	170	850	-	8.7	5.9	-
11		(pKa1) 7.20 (pKa2) 12.4 (pKa3)								7.1	5	-